

# BRITISH HEART JOURNAL

## Editorial

### Coronary surgery without cardiopulmonary bypass

The drive towards cost containment is changing clinical practice, and the emphasis is now on less invasive procedures and simplicity.<sup>1</sup> The economic arguments for coronary angioplasty (PTCA) are currently limited by high restenosis rates and the need for further intervention within the first three months (> 30%).<sup>2-4</sup> Though from a surgical perspective the results of coronary artery bypass grafting (CABG) are clearly superior, excessive surgical waiting times and the lesser immediate expense are used to justify diversification of PTCA to patients with multi-vessel disease.<sup>5</sup> These arguments are reinforced by adding to the equation the damaging effects of cardiopulmonary bypass.

Interaction between blood and foreign surfaces activates complement and neutrophils to produce a whole body inflammatory response.<sup>6</sup> Intrapulmonary sequestration of white cells, with generation of free radicals and protease enzymes, causes the interstitial oedema generally implicated in the need for postoperative ventilation.<sup>7</sup> These mechanisms, together with systemic microembolism also have effects on the brain and kidney.<sup>8,9</sup> The neuropsychological consequences of cardiopulmonary bypass, which are well documented and perhaps over-emphasised, generate anxiety in the well-informed patient.<sup>10-12</sup> They argue in favour of an expeditious surgeon and short bypass times (< 60 minutes), or indeed against cardiopulmonary bypass. Clearly, there are short-term clinical reasons to avoid cardiopulmonary bypass and to these can be added the cost of equipment (about £500 in disposables), intensive care, and extended hospital stay. Many aspects of cardiac surgery have been taken for granted since development of the specialty in the late 1950s. At the Oxford Heart Centre efforts to simplify cardiac surgery have recently extended to performing CABG without cardiopulmonary bypass in selected patients. Coronary surgery is undertaken without opening a cardiac chamber and consequently it is not necessary to divert blood from within the heart. With continued ventilation of the lungs and unimpaired pulmonary blood flow there is no need for an oxygenator. The only technical requirement for CABG is a bloodless anastomotic field. This can be achieved by temporary coronary occlusion while the heart continues to support the circulation through uninterrupted cardiac action. Besides the historical documentation of this approach we have become increasingly aware from PTCA experience that coronary occlusion and myocardial ischaemia are surprisingly well tolerated for up to 15-20 minutes.<sup>13-16</sup> This is longer than the time needed to isolate a coronary artery in the beating heart, open the vessel, and apply either an internal mammary or saphenous vein graft. The PTCA principle of addressing the culprit lesion by non-pump CABG could be applied to certain high risk patients but the method is mostly used for those in

whom complete revascularisation can be undertaken through the left anterior descending and right coronary arteries.

#### Lessons from previous experience

In the early 1950s, before cardiopulmonary bypass came into use, coronary endarterectomy, coronary excision with interposition vein grafts, and both saphenous vein and internal mammary artery bypass were performed experimentally and on patients without significant morbidity or mortality.<sup>14-16</sup> William Longmire first performed an anastomosis between the left internal mammary artery and the left anterior descending coronary artery in 1958. Longmire recalls "At the time we were doing the coronary thromboendarterectomy procedure, we also I think performed a couple of the earliest internal mammary to coronary anastomoses. We were forced into it when the coronary artery we were endarterectomising disintegrated and in desperation we anastomosed the internal mammary artery to the distal end of the right coronary and later decided it was a good operation." Sabiston performed a right coronary saphenous vein graft in 1962 and DeBakey succeeded with a saphenous vein bypass of the left coronary artery without extracorporeal circulation in 1964, though the event was published only after 7 year angiographic follow up showed that the graft was patent.<sup>16</sup>

Widespread adoption of cardiopulmonary bypass and cold cardioplegic arrest made CABG easy and provided the stimulus for a dramatic increase in the number of procedures from 1968 onwards.<sup>17</sup> This stifled further efforts to operate on the beating and unsupported heart at a time when vascular surgical techniques remained primitive. Nevertheless, a few surgeons persisted. Ankeney in 1972 described 143 patients in whom cardiopulmonary bypass was not used.<sup>18</sup> Buffolo *et al* reported coronary bypass by simple interruption of coronary flow in 1985 and the same year Frederico Benetti and his group described their initial experience from Buenos Aires.<sup>19,20</sup> Benetti's experience of more than 2000 cases was stimulated by limited resources. Non-pump CABG allowed a substantially greater throughput of patients than would otherwise have been possible.<sup>20</sup> Postoperative angiography has shown no significant difference in graft patency between bypass and non-bypass patients when the saphenous vein or the internal mammary artery was used.<sup>20</sup>

Others have followed Benetti's lead for elective, emergency, and re-operative coronary bypass. Pfister *et al* of the Washington Hospital Centre, reported 220 operations off bypass, comparing the outcome with 220 conventional operations matched for number of grafts, left ventricular function, and date of operation.<sup>21</sup> They

concluded that selected patients with disease of left anterior descending and right coronary arteries can safely undergo CABG without cardiopulmonary bypass and that left ventricular function was better preserved than after cold cardioplegic arrest.

The superior preservation of left ventricular function despite periods of "unprotected" regional ischaemia followed by reperfusion was described by Akins *et al* in a comparative study of CABG performed with and without extracorporeal circulation.<sup>22</sup> They found that postoperative septal wall motion was abnormal in patients operated on with cardiopulmonary bypass, aortic cross clamping, and myocardial preservation techniques, whereas those operated without had either no change or an improvement in septal motion after revascularisation. Benetti *et al* explored this aspect by performing intraoperative left ventricular biopsies and showed superior preservation of the mitochondria in the non-bypass patients.<sup>23</sup> Clearly myocardial stunning does not become important in non-pump patients despite occlusion times of 10-15 minutes.<sup>24-25</sup> Myocardial reperfusion injury has a central role in the pathophysiology of myocardial stunning after periods of coronary occlusion, but the effects of obstructing a previously normal vessel are not the same as for an obstructed or severely narrowed diseased vessel. A clue to the absence in stunning after non-pump reperfusion, compared with reperfusion after global ischaemia during cardiopulmonary bypass, is that the interaction between blood and foreign surfaces activates leucocytes which are implicated in the mechanism of reperfusion injury.<sup>26</sup>

Collectively, the data from these groups suggest that non-pump CABG procedures are safe, cost effective, and advantageous—notably, for those with impaired ventricles, for hypertensive patients, certain reoperations, and for those with carotid and renal disease.<sup>27</sup> Those who refuse blood transfusion benefit through preserved coagulation and minimal blood loss. The method is best applied for those in whom revascularisation is complete with one to three grafts in the accessible territories.<sup>28-29</sup> For those at high risk of morbidity from cardiopulmonary bypass—for example, those with a calcified (eggshell) aorta or carotid occlusion—grafting of a culprit lesion in an accessible territory with one or both internal mammary arteries is preferable to the near certainty of cerebral injury.<sup>30</sup>

#### Technical aspects of non-pump coronary surgery

The Oxford experience is limited but we have used both vein grafts and the left internal mammary artery and have achieved extensive right coronary endarterectomy on the beating heart. With appropriate planning the operation is safe and causes surprisingly little haemodynamic instability. Anaesthetic methods are modified to allow extubation in the immediate postoperative period. The operating conditions are clearly not as good as for cardioplegic arrest but are not dissimilar to those of intermittent aortic cross clamping with a fibrillating heart. The occlusive, stay sutures provide access and stability to the coronary artery and, with practice, hand/eye coordination adapts to the rhythmic movement. A certain degree of surgical skill is needed to suture a 1.5 mm mammary artery to a moving target of 2 mm diameter. It will be difficult to match Benetti's results, but experience and familiarity with the approach leads to greater ease, accuracy, and confidence. Benetti grafts the circumflex coronary from the front and Faro has used left thoracotomy for reoperative circumflex grafts, without bypass.<sup>31</sup> We reserve non-pump CABG for tightly occluded or highly stenotic well collateralised and easily accessible lesions of

the left anterior descending or right coronary arteries. The issue of complete revascularisation in non-pump operations is of concern. Interventional cardiology has usurped many of the straightforward one and two graft cases, but with informed consent based on the randomised trials of CABG versus PTCA for multivessel disease, more patients with the combination of left anterior descending right coronary artery disease are likely to opt for surgery.<sup>2-5</sup> The fact that PTCA of the culprit lesion (often with sacrifice of diagonal or marginal branches) gained acceptance in the medical community is an argument in support of non-bypass procedures, given that PTCA offers less protection to the patient than non-pump CABG. However, a note of caution is needed. In the discussion of Pfister's paper, Gundry of Loma Linda, described a similarly encouraging in hospital experience with 128 patients but an inordinate number of graft anastomotic stenoses and narrowings occurred at the site of the loops placed around the diseased vessel. This, together with several unexpected late deaths, caused the Loma Linda surgeons to abandon the method.<sup>21</sup>

Further investigations are appropriate in certain categories of patient because non-bypass CABG can be performed without added risk and at a cost similar or less than multivessel PTCA. What then is the future for CABG? Cardiopulmonary bypass is still necessary to perform multiple grafts, including those in the circumflex territory, and when there are combinations of lesions which carry exorbitant risk. Myocardial protection with cardioplegia provides a motionless and bloodless field that expedites surgery. Coronary surgery without cardiopulmonary bypass is already applicable in the circumstances described but its use may expand with the use of axial flow pumps, which provide circulatory support without the need for extracorporeal circulation. With continued innovation it is likely that CABG (a closed cardiac operation) will soon be performed routinely without the heart/lung machine.

In conclusion, coronary surgery without cardiopulmonary bypass is safe, eliminates both the need for blood transfusion and the damaging effects of cardiopulmonary bypass, and allows extubation on the operating table. Patients can be discharged from hospital on the fourth or fifth postoperative day. The disadvantages of the method are the limitation to two vessel disease, a technically more challenging anastomosis, and a question mark over graft patency if snares are used. However, with costs equivalent to angioplasty and a longer lasting result use of this method must increase.

STEPHEN WESTABY

*Oxford Heart Centre, John Radcliffe Hospital,  
Headington, Oxford OX3 9DU*

- Westaby S. Cutting costs in cardiac surgery. Time to break the mould. *Surgery* 1991;86:2040-55.
- Vacek JL, Rosamund TL, Stites WH, Rowe SF, *et al*. Comparison of percutaneous transluminal coronary angioplasty versus coronary artery bypass grafting for multivessel coronary artery disease. *Am J Cardiol* 1992;69:592-7.
- Weintraub WS, Jones EL, King SB, Craver J, *et al*. Changing use of coronary angioplasty and coronary bypass surgery in the treatment of chronic coronary artery disease. *Am J Cardiol* 1990;65:183-8.
- Weintraub WS, King SB, Jones EL, Douglas JS, *et al*. Coronary surgery and coronary angioplasty in patients with two-vessel coronary artery disease. *Am J Cardiol* 1993;71:511-7.
- Berrekouw E, Hoogsteen J, Van Wandelen M, Verkroost J, *et al*. Bilateral mammary artery surgery or percutaneous transluminal coronary angioplasty for multivessel coronary artery disease? An analysis of effects and costs. *Eur Heart J* 1989;10:61-70.
- Butler J, Rocker G, Westaby S. Inflammatory response to cardiopulmonary bypass. *Ann Thorac Surg* 1993;55:552-9.
- Kirklin JK, Westaby S, Blackstone EH, *et al*. Complement and the damaging effects of cardiopulmonary bypass. *J Thorac Cardiovasc Surg* 1983;86:845-57.
- Blauth CL, Arnold JV, Schulenberg WE, McCartney AC, Kohner EM,

- Taylor KM. Cerebral microembolism during cardiopulmonary bypass. *J Thorac Cardiovasc Surg* 1988;95:668-76.
- 9 Parker FB, Marvasti MA, Bove EL. Acute neuropsychological consequences of coronary artery bypass surgery. The role of atherosclerotic emboli. *Thorac Cardiovasc Surg* 1985;33:207-9.
  - 10 Hammete TA, Hastings JE. Neuropsychologic alterations after cardiac operation. *J Thorac Cardiovasc Surg*;1988;96:326-31.
  - 11 Smith PLC, Treasure T, Newman SP, *et al.* Cerebral consequences of cardiopulmonary bypass. *Lancet* 1986;i:823-5.
  - 12 Sotaniemi KA, Mononen H, Hokkanen TE. Long term cerebral outcome after open heart surgery: a five year neuropsychological follow up study. *Stroke* 1986;17:410-16.
  - 13 Carrel A. On the experimental study of the thoracic aorta and the heart. *Ann Surg* 1910;51:83-95.
  - 14 Murray G, Porcheron R, Hilario J, Rochlau W. Anastomosis of a systemic artery to the coronary. *Can Med Assoc J* 1954;71:594-7.
  - 15 Kolesov VI. Mammary artery-coronary artery anastomosis as a method for treating angina pectoris. *J Thorac Cardiovasc Surg* 1967;54:535-44.
  - 16 Sabiston DC. The coronary circulation. *Johns Hopkins Med J* 1974;134:314-29.
  - 17 Favaloro RG, Effler DB, Groves LK, Sheldon WC, Sones FM. Direct myocardial revascularisation by saphenous vein graft. Present operative technique and indication. *Ann Thorac Surg* 1970;10:97-111.
  - 18 Ankeney JL. To use or not to use the pump oxygenator in coronary bypass operations. *Ann Thorac Surg* 1975;19:108-9.
  - 19 Buffolo E, Andrade JCS, Succi J, Leao LEV, Galluci L. Direct myocardial revascularisation without cardiopulmonary bypass. *Thorac Cardiovasc Surg* 1985;33:26-9.
  - 20 Benetti FJ, Naselli G, Wood M, Geffner L. Direct myocardial revascularisation without extracorporeal circulation. Experience in 700 patients. *Chest* 1991;100:312-6.
  - 21 Pfister AJ, Zaki MS, Garcia JM, *et al.* Coronary artery bypass without cardiopulmonary bypass. *Ann Thorac Surg* 1992;54:1085-92.
  - 22 Akins CW, Boucher CA, Pohost GM. Preservation of interventricular septal function in patients having coronary artery bypass grafts without cardiopulmonary bypass. *Am Heart J* 1984;107:304-9.
  - 23 Benetti FJ, Naselli G, Garcia-Beltrame A, Scordo D, Miley J. Hallazgos de la biopsia de miocardio a pacientes sometidos a cirugía coronaria directa sin circulación extracorporea. *Medicina* 1986;300:46-52.
  - 24 Braunwald E, Klorer RA. The stunned myocardium: prolonged postischemic ventricular dysfunction. *Circulation* 1982;66:1146-9.
  - 25 Breisblatt W, Stein K, Wolfe CJ, *et al.* Acute myocardial dysfunction and recovery: a common occurrence after coronary bypass surgery. *J Am Coll Cardiol* 1990;15:1261-9.
  - 26 Byrne JG, Appleyard RF, Lee CC, *et al.* Controlled reperfusion of the regionally ischemic myocardium with leukocyte depleted blood reduces stunning, no reflow and infarct size. *J Thorac Cardiovasc* 1992;103:66-72.
  - 27 Fanning WJ, Kakos GS, Williams TE. Re-operative coronary artery bypass grafting without cardiopulmonary bypass. *Ann Thorac Surg* 1993;55:486-9.
  - 28 Laborde F, Abdelmequid I, Piwnica A. Aorto coronary bypass without extracorporeal circulation. Why and when? *Eur J Cardiothorac Surg* 1989;3:152-5.
  - 29 Archer K, Ott DA, Parravicini R, *et al.* Coronary artery revascularisation without cardiopulmonary bypass. *Tex Heart Inst J* 1984;11:52-7.
  - 30 Arsiwala SS, Bedi HS, Sharma VK, Trehan N. Coronary artery bypass in patients with calcified aorta (letter) *Ann Thorac Surg* 1991;51:348.
  - 31 Faro RS, Javid H, Najafi H, Serry C. Left thoracotomy for reoperations for coronary revascularisation. *J Thorac Cardiovasc Surg* 1982;84:453-5.